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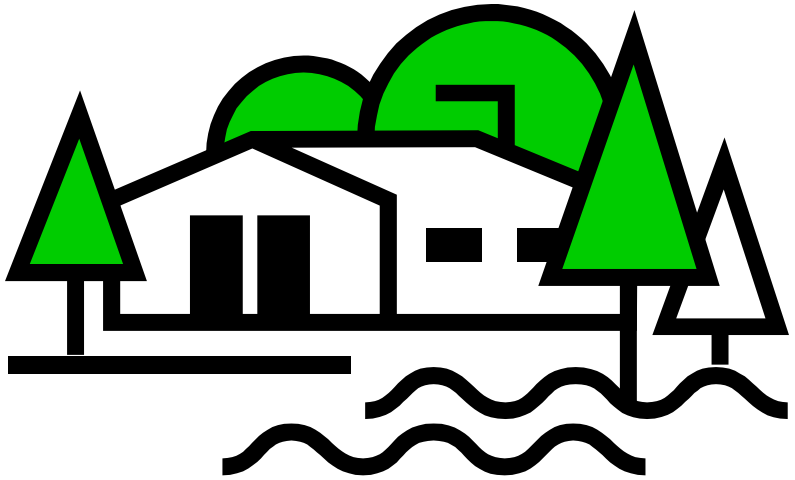
Building Technologies Program

Building America
U.S. Department of Energy
Research Leading to Zero Energy Homes

Rebuilding a Flood Damaged Home



Purpose of this training course

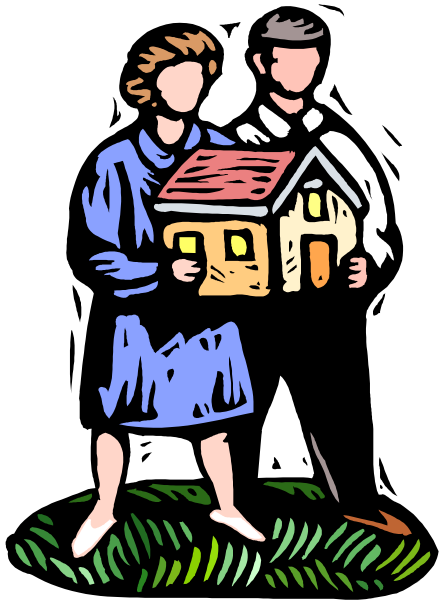
- Give builders and homeowners best available information on home reconstruction to reduce potential future flood damage while improving comfort and reducing energy use.

Introduction – The Gulf Coast and New Orleans have suffered unprecedented flood damage

All kinds of residential areas have been flooded by the hurricanes

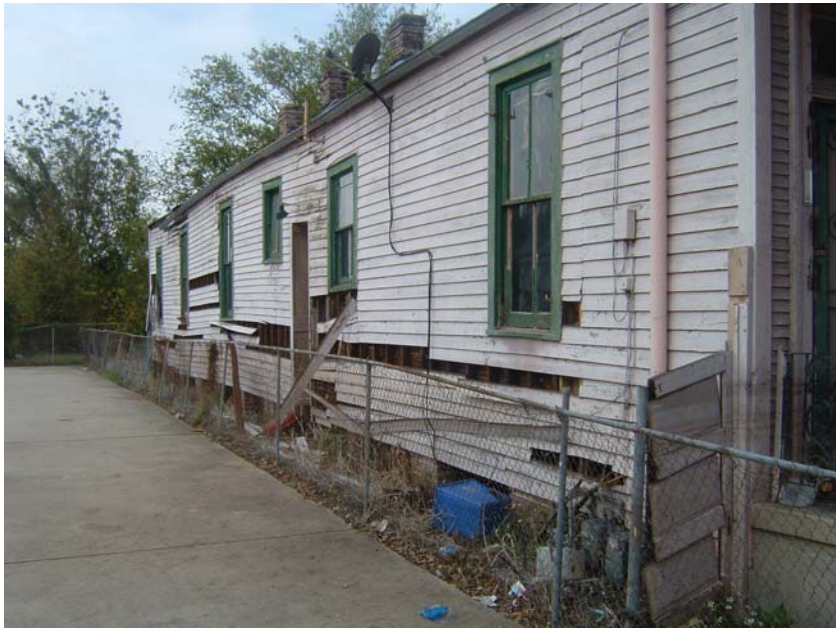
Response to Floods - FEMA

- Substantial damage
  (repairs cost ≥50% of preflood market value)
  - Elevate
  - Relocate
  - Buy-out
- Not substantially damaged
  (repairs cost <50% of preflood market value)
  - Wet floodproofing (focus of this Workshop)



See: http://www.fema.gov

Post-flood New Orleans homes



- Previous condition or flood related damage will preclude some homes from restoration

Post-flood New Orleans homes

- Many well maintained older homes and newer homes can be candidates for restoration

Elevate—Examples

Let's get started on recovery

Post-Flood Activities

Refer to the American Red Cross's, *Repairing Your Flooded Home*

http://www.redcross.org/static/file_cont333_lang0_150.pdf

Post-Flood Activities

- *Drying*
- *Cleaning*
- *Draining Walls*

http://www.ornl.gov/sci/res_buildings/FEMA-attachments/InitialRestorationFloodBldg--FINAL.pdf

Post-Flood Activities

- *Sanitizing*
- *Mold Removal*

http://www.ornl.gov/sci/res_buildings/FEMA-attachments/InitialRestorationFloodBldg--FINAL.pdf

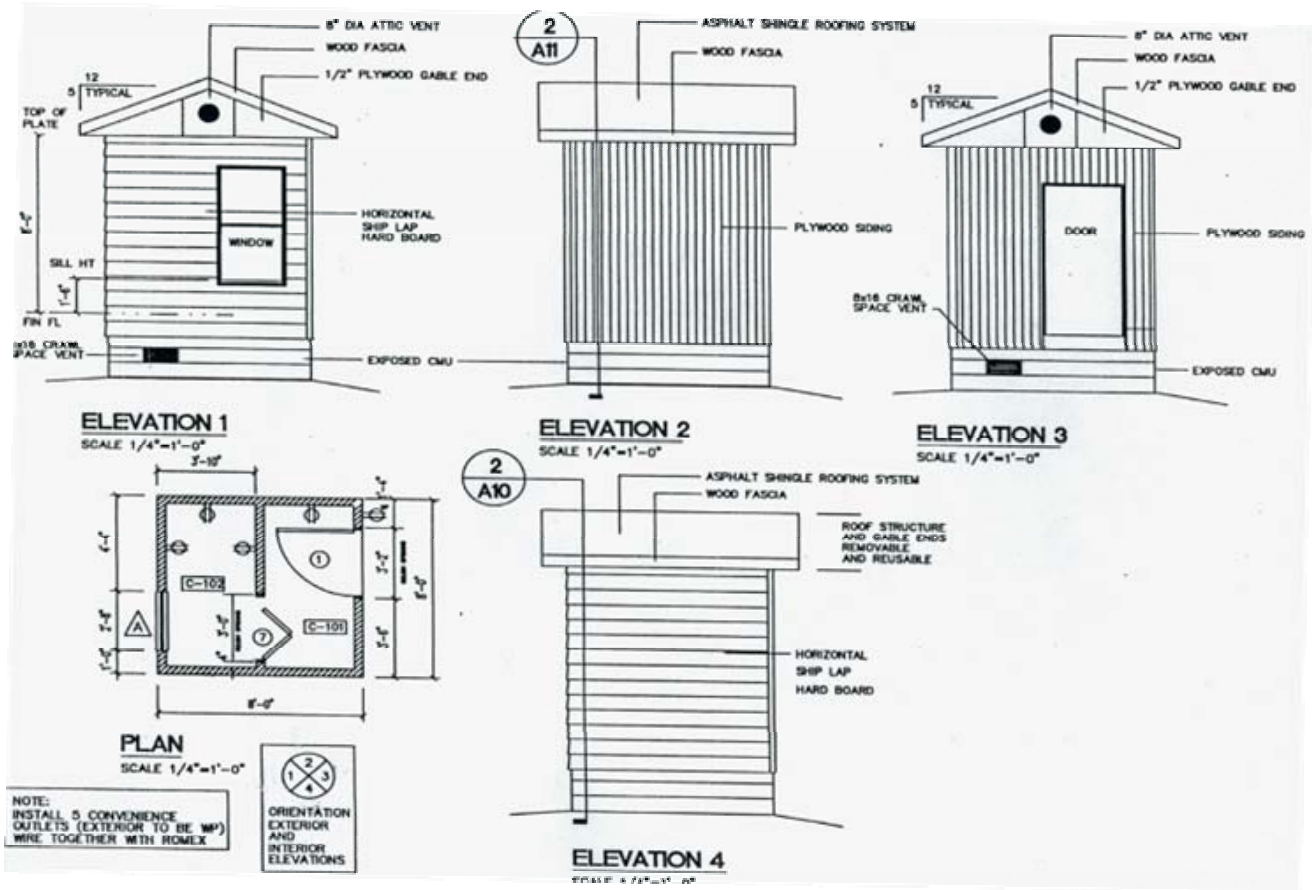
It's time to rebuild.

- What have we learned to improve future flood damage resistance?
  - From ORNL/Tuskegee University testing
  - From inspection of New Orleans homes

ORNL & Tuskegee University have been doing flood damage research since 2000.

Reports at http://www.ornl.gov/sci/res_buildings/NaturalDisaster.htm

Field Test Modules at Tuskegee



Reconstruction Principle

Exclude Water **—**this is at best difficult to accomplish

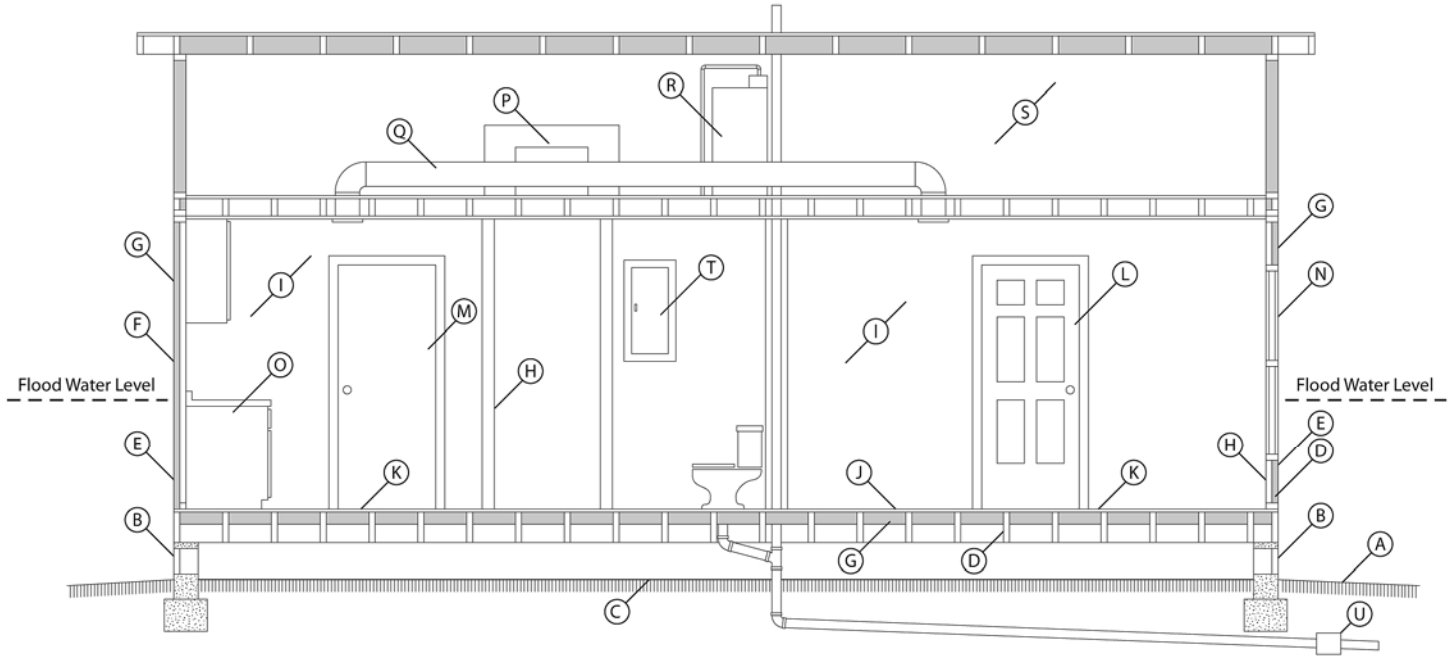
Multiple tries at Dry Floodproofing failed in Tuskegee Tests

Reconstruction Principles

Encourage Drying —acknowledges the probability that water will get into a system like the wall

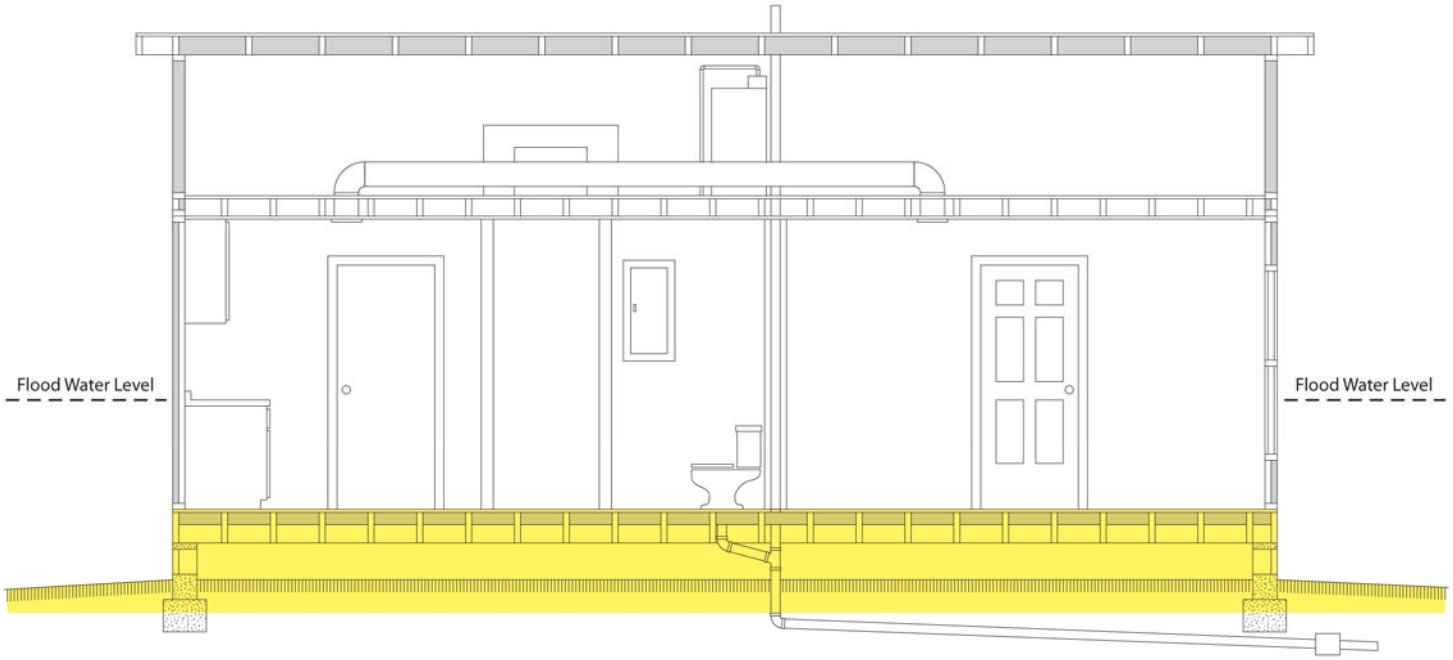
GOOD – Wall System	***POOR – Wall System***
INSIDE	INSIDE
Latex Paint	Oil Based Paint or Vinyl Wall Covering
Gypsum Wallboard	Gypsum Wallboard
SPUF Insulation	SPUF Insulation
Plywood sheathing	Plywood sheathing
House Wrap	House Wrap
Fiber Cement Lap Siding	Plywood Panel Siding (e.g. T-111)
Latex Paint	Oil Based Stain
OUTSIDE	OUTSIDE

Flood damage resistant reconstruction



Numerous things can be done throughout the home – let's focus on the envelope first

Site drainage, foundation, crawl space

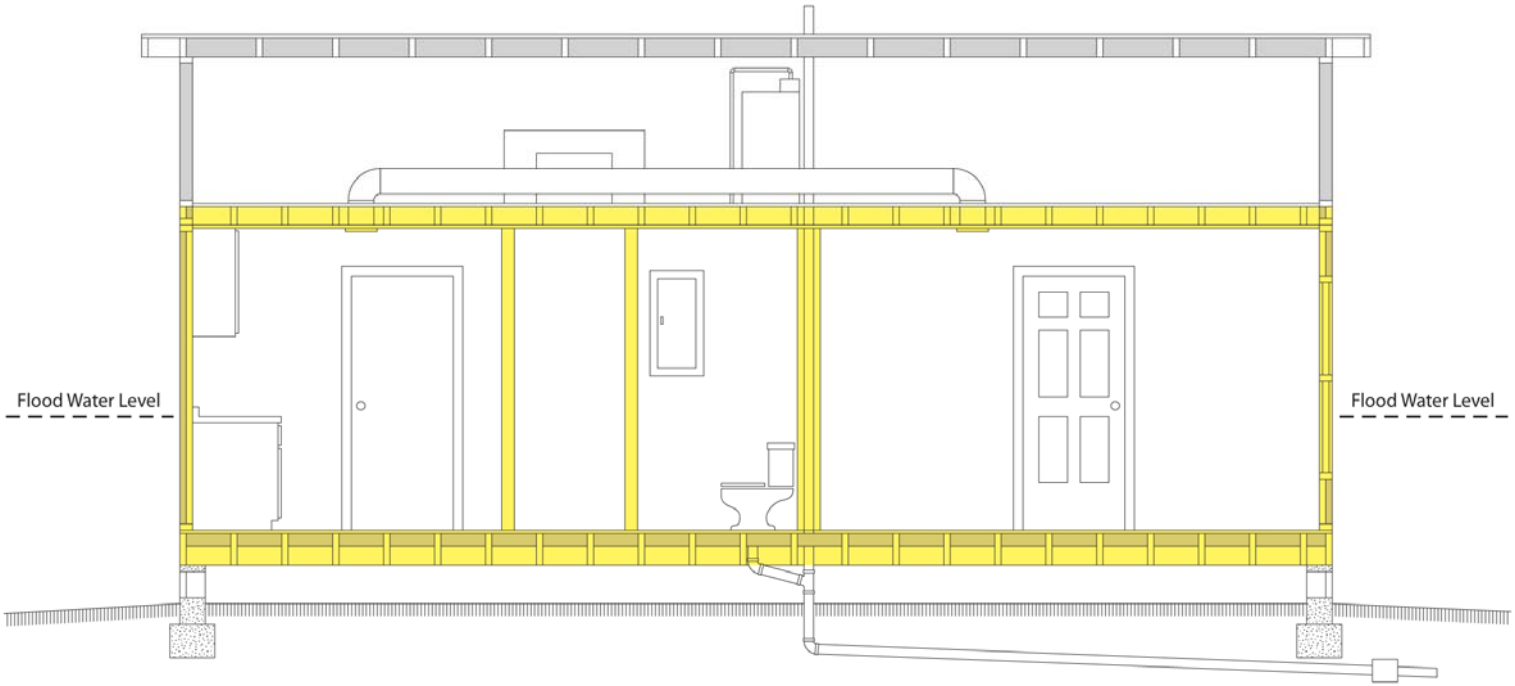


Flood Vent

Site drainage, foundation, crawl space

- Completely dry crawl space
- Slope site away from house
- Install flood vents
- Regrade crawl space to drain to perimeter
- Cover dirt with vapor barrier
- Seal connections to house

Floors—subflooring, framing, finish flooring



Subflooring, framing

- Promote drying by removing
  - Wet carpeting
  - Flooring that traps moisture
  - Wet insulation
- Concrete floors usually OK
- Wood sub-floor and joists OK if able to dry

POOR - Floor System

INSIDE

Vinyl Floor Covering or Wet Carpet

Plywood Sub-flooring

Wood Joists

SPUF or Wet Fiberglass Insulation

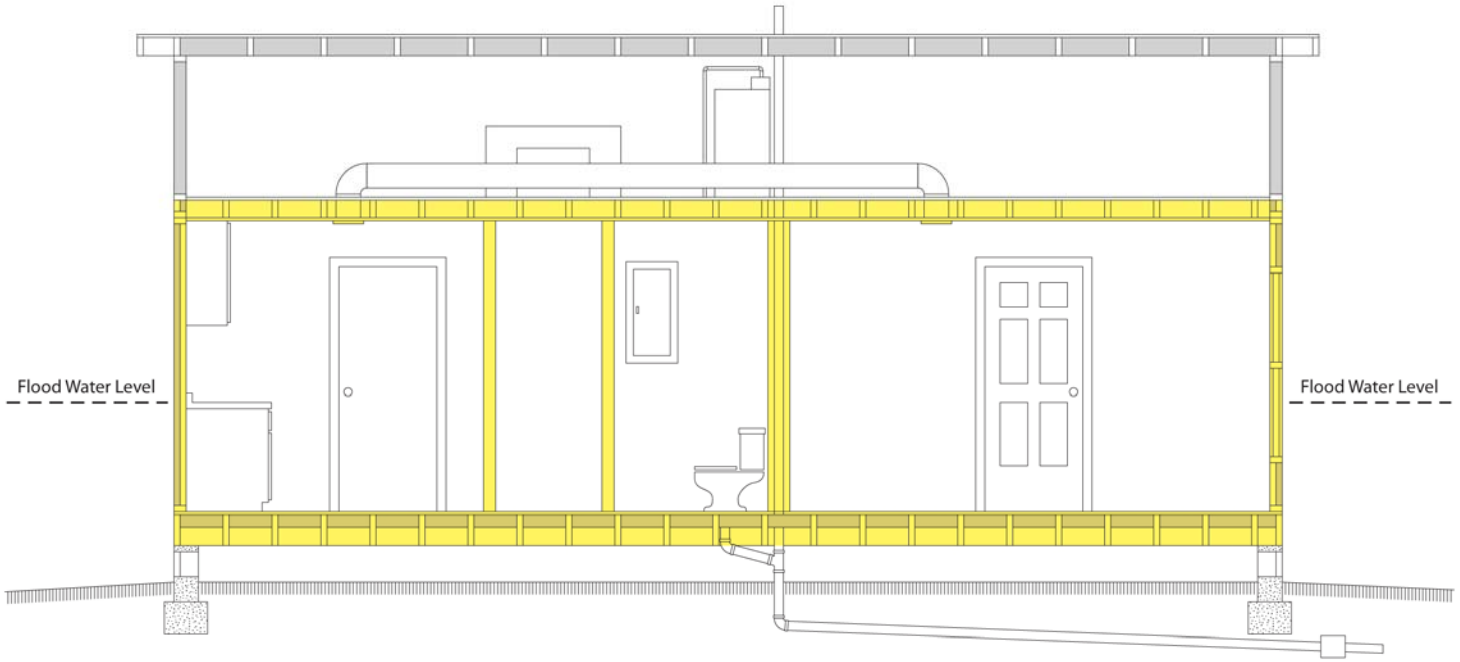
CRAWL SPACE

Finish Flooring

Which flooring materials could be reused?

- Carpet and pad (no)
- Wood (?)
- Wood composite (?)
- Sheet vinyl (?)
- Ceramic/quarry tile (yes)

Walls—framing, sheathing, siding, gypsum wallboard, finishes, insulation



Wall Framing, Sheathing

Tuskegee and New Orleans Experience—No damage


New Orleans


Tuskegee


New Orleans

Siding

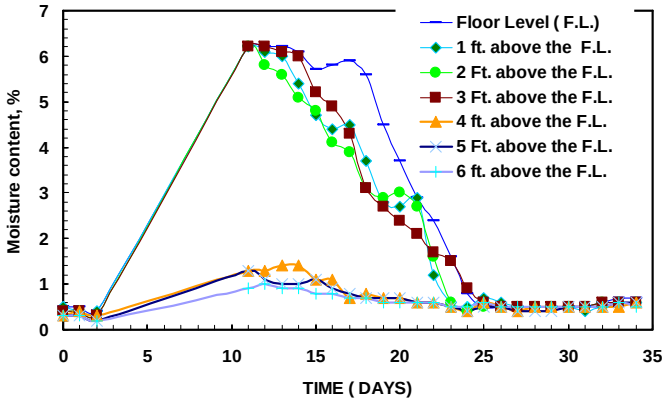
Plywood

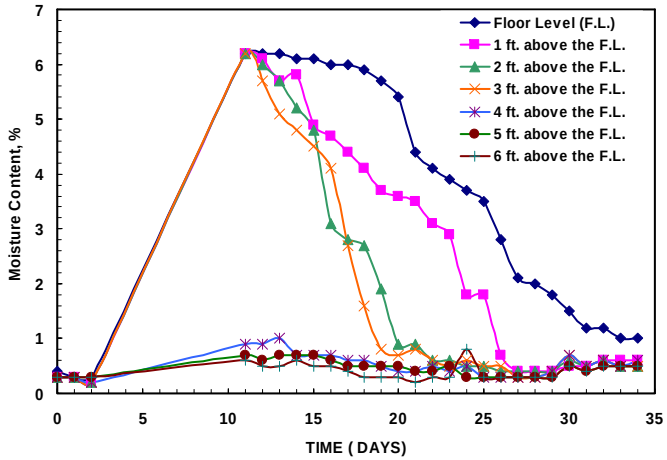
Vinyl

Fiber cement

Gypsum Wallboard

Tuskegee and New Orleans Experience—Fibrous insulation remained moist and encouraged mold growth on walls





Gypsum Wallboard

Which gypsum wallboard materials could be reused?

- Common paper faced wallboard—drywall (?)
- WR Greenboard (no)
- Fiber-reinforced gypsum interior wall panels—ASTM C-1278 (?)
- WR Fiber-reinforced gypsum interior wall panels (yes)
- Other WR gypsum wall board products (?)

Wall finishes

Flaking paint

Typical mold

Vinyl Wallpaper

Restored Post flood

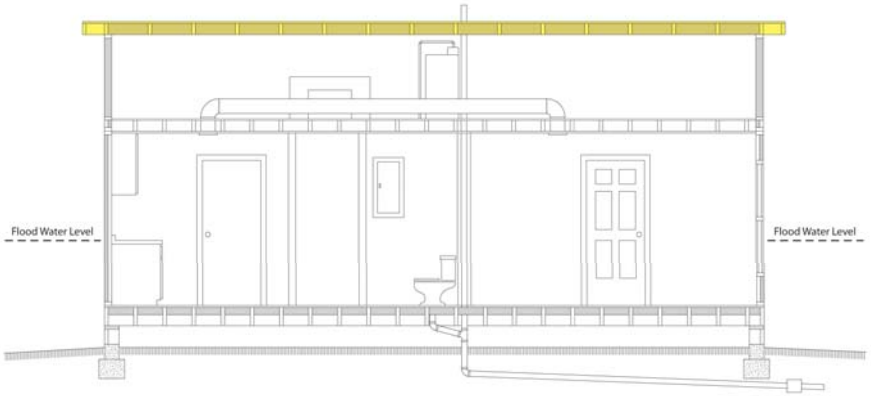
Wall and floor insulation
Spray polyurethane foam (SPUF)

Windows and Doors




If the roof has been damaged

Replacement roofs stop flooding “from above” and provide safe haven for equipment



Not All Roofs Performed Equally

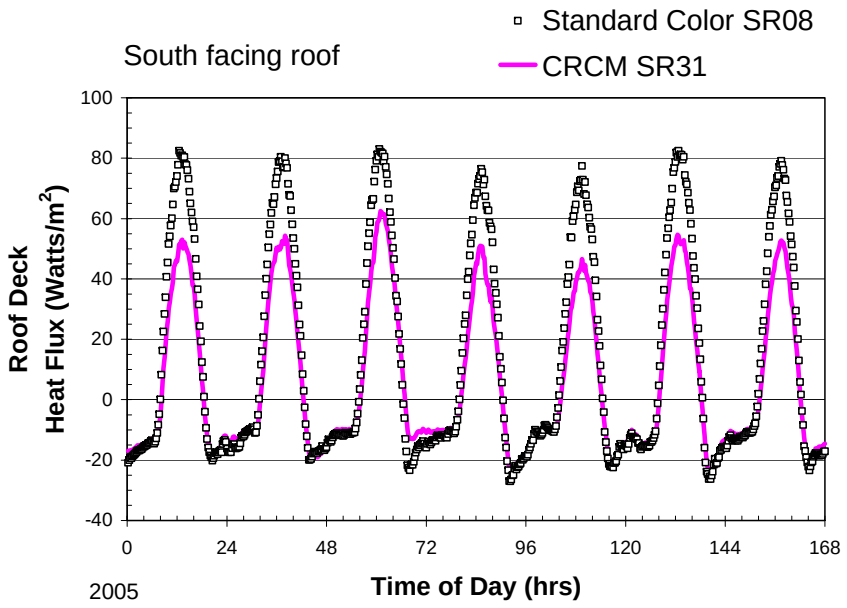
See: www.fema.gov/pdf/hazards/nhp_fema55.pdf

What can be done to improve roof performance on existing homes?

- Convert to hip roof or reinforce gable ends
- Remove or reinforce overhangs
- Consider making attic unvented conditioned space to house equipment
- Do not overlay existing shingles with a new membrane
- Use infra-red reflective, hurricane resistant roof membranes (metal, shingle, tile)

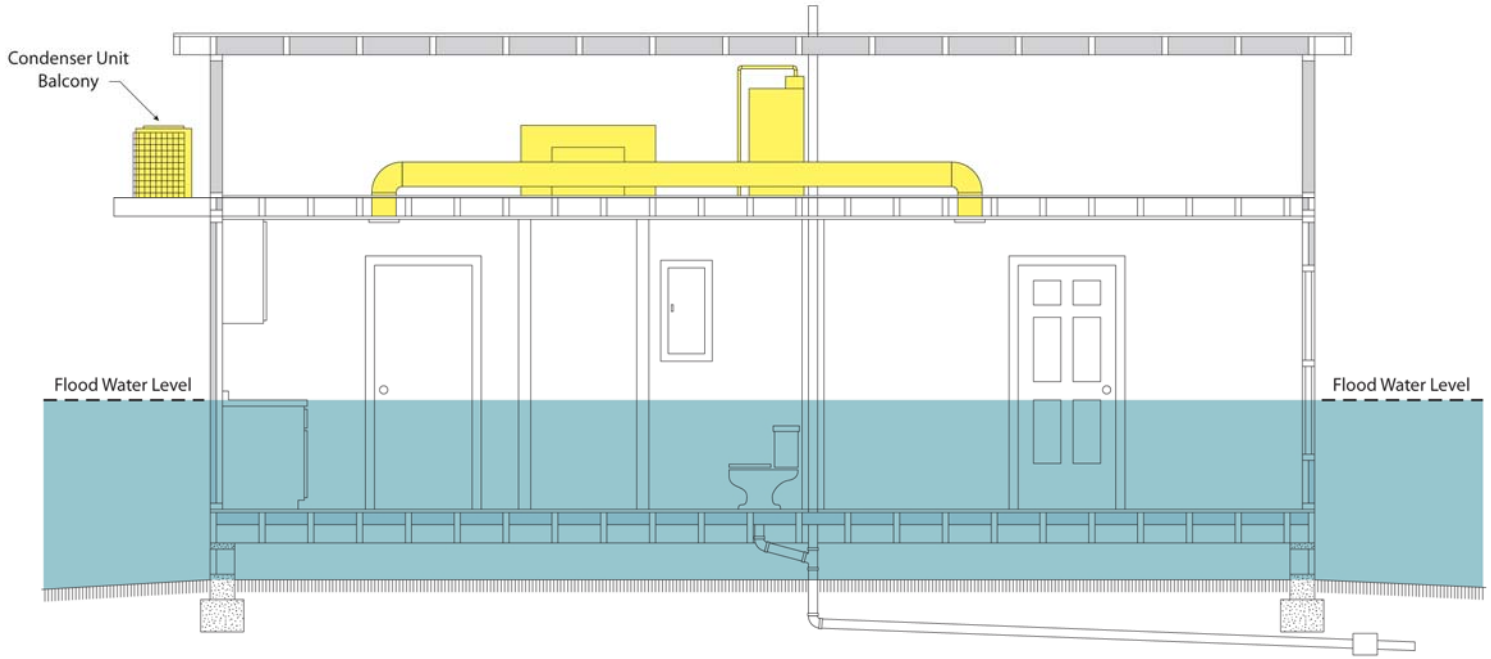
Don’t Overlay Existing Roofing

Use Infrared Reflective Roofing



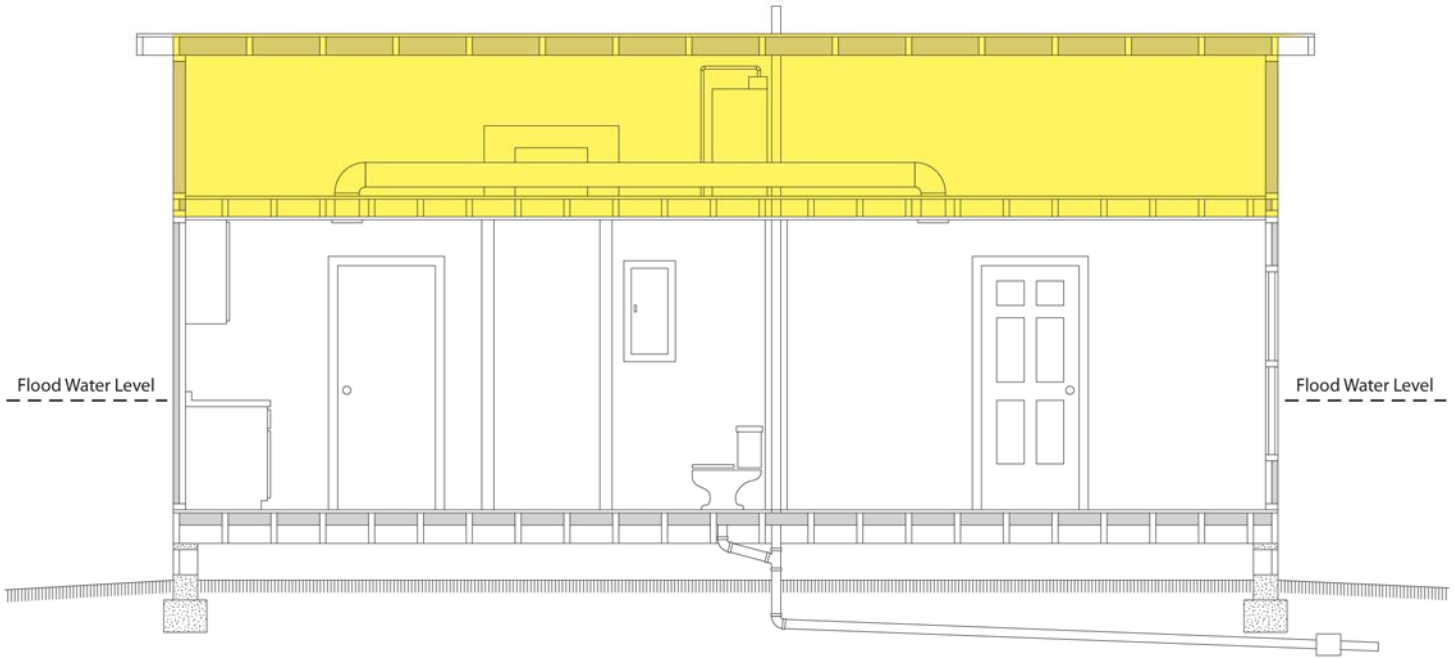
IR reflective roofing (magenta) lowers the solar heat flux through the roof by 15 to 30% when compared with a standard (black symbols) roof of the same material. IR reflective roofs are currently available in painted metal, shingle, and tile.

Strategies for flood damage resistant equipment and appliances



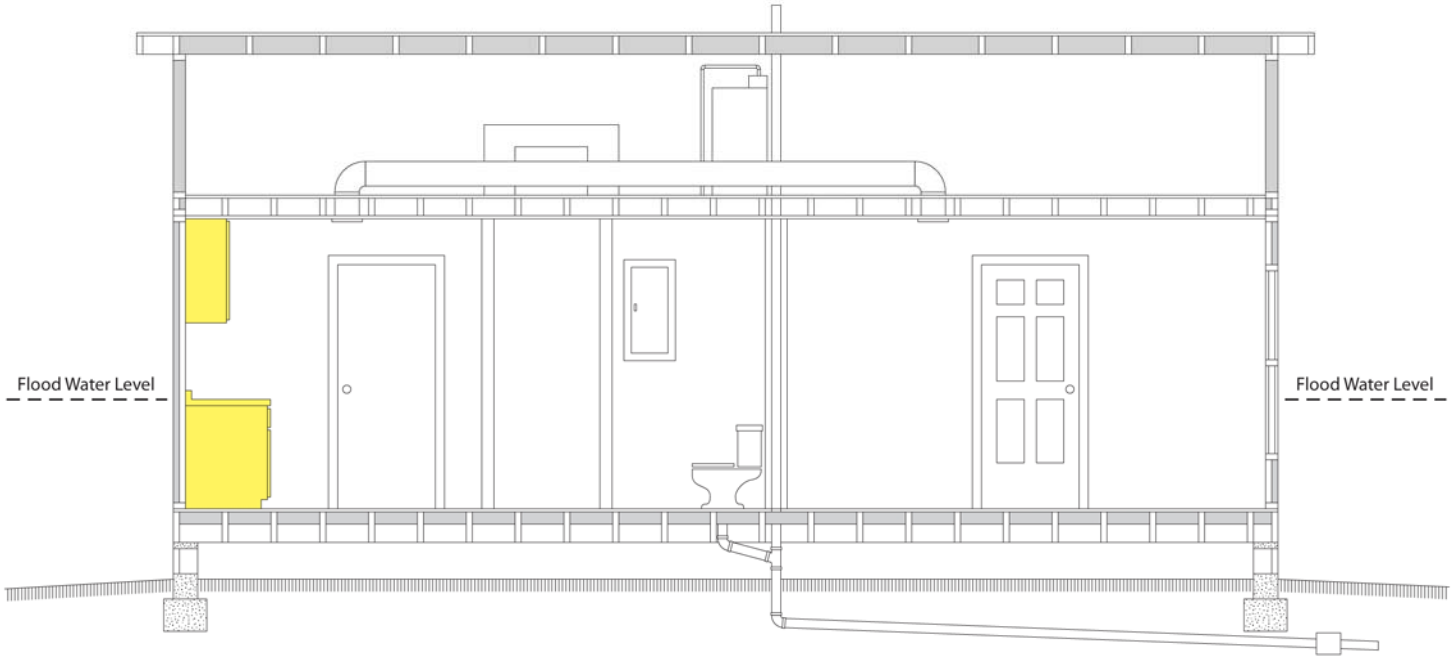
Raise HVAC equipment above potential flood level

Associated Attic Modifications



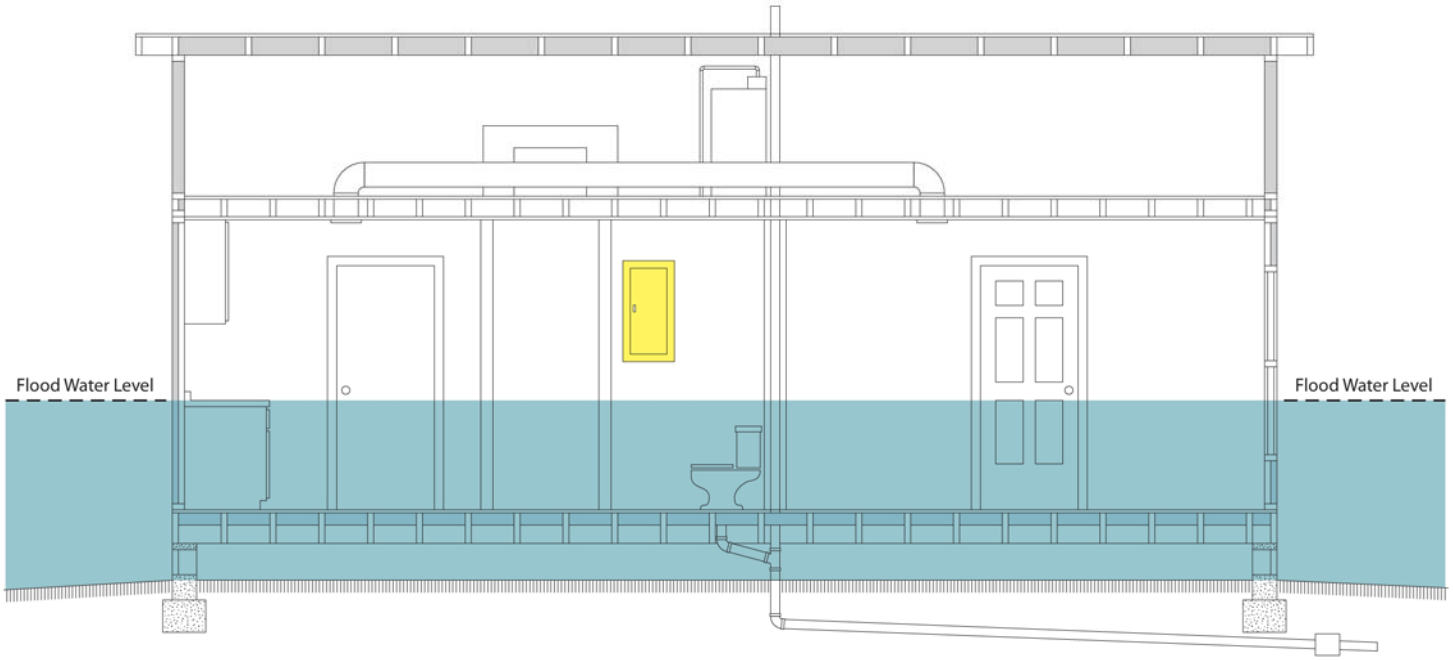
Raise water heater & laundry above potential flood level

Kitchen and Bath Cabinets



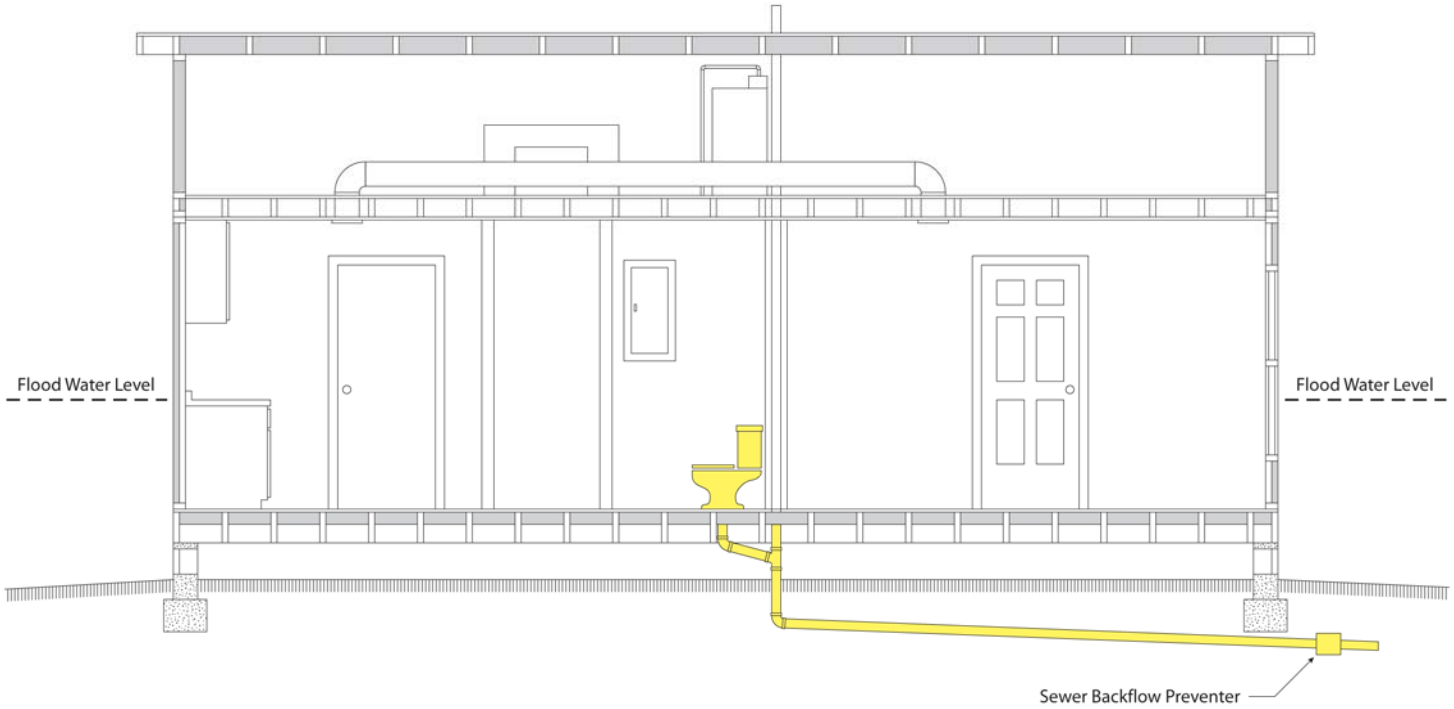
Kitchen cabinets and appliances

Restoring the electrical system

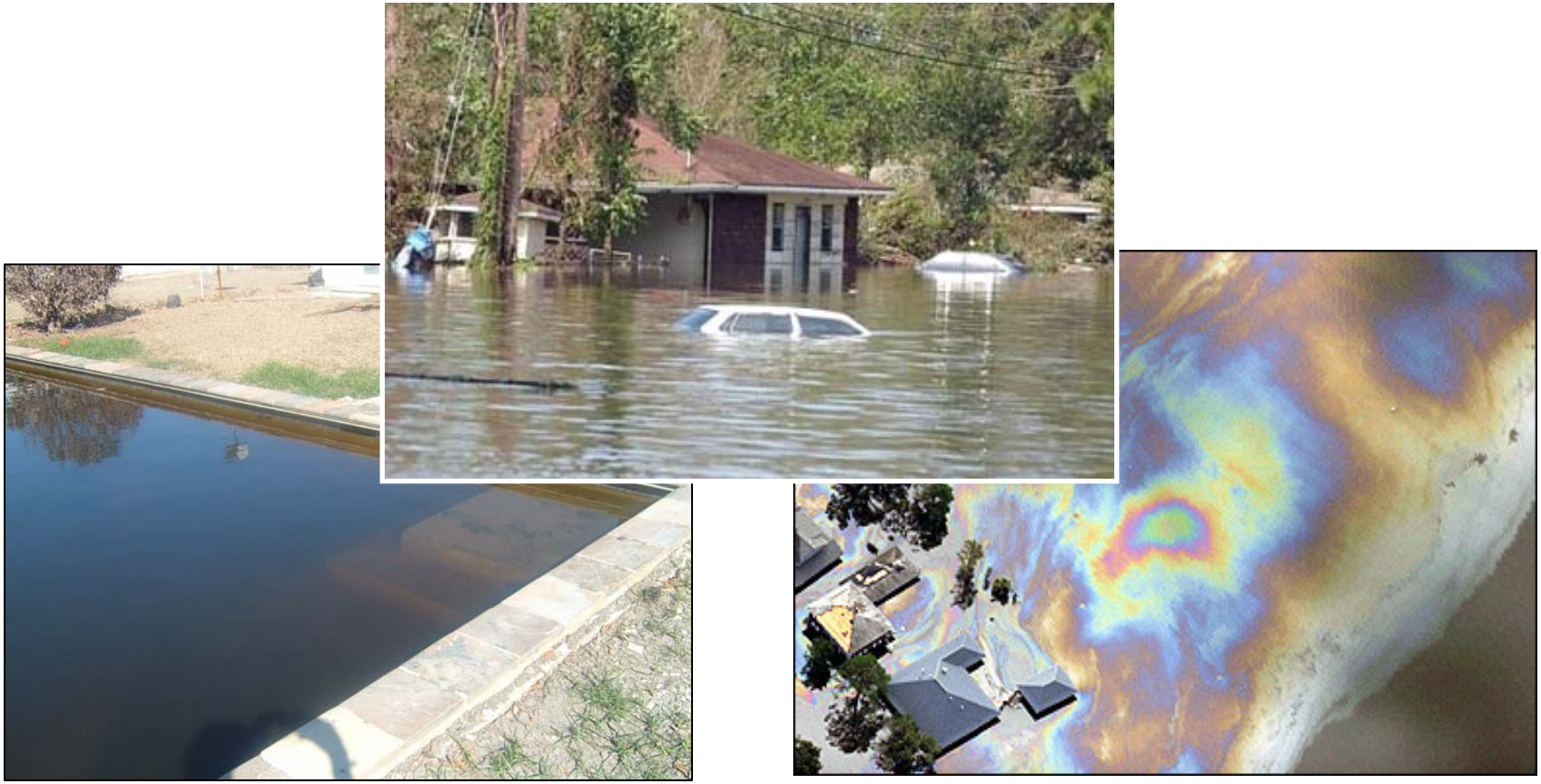


Electrical system

Sanitary Sewer



Katrina – Floodwater contamination a potential issue in New Orleans



If flood damage resistant construction isn't required by code **why** would a homeowner want to use it?

- Reduced vulnerability to future floods
  - Less disruption (faster return)
  - Lower recovery cost
- Reduced heating and cooling energy costs
  - Improved comfort

Cost and benefits - typical 1800 S.F. home, Gulfport, MS restored in-kind versus restored with flood damage resistance

Item	Cost (in-kind)	Cost (flood-resistant)
• Wall Insulation	$775	$2380
• Floor Insulation	$1620	$4860
• Attic Insulation	existing	$2430
• Front Door	$600	$250
• Windows	$2200	$1700
• Heat Pump	$1160	$790
• Totals	$6355	$12410

(the costs cover only that portion of the restoration where the costs differ among the options and not the total cost of restoration)

The reasons for the cost differences are as follows:

- Wall and floor insulation changes from fiberglass batt (in-kind) to SPUF (flood resistant)
- Under roof deck insulation is added to flood resistant to enable HVAC and ducts to be relocated above flood level
- Front door is solid wood (in-kind) and steel foam filled (flood resistant)
- Windows are wood (in-kind) and solid vinyl (flood resistant)
- Heat pump is 4 tons (in-kind) and 2 tons (flood resistant) due to the improved envelope

Energy Savings - based on design simulations of heating and cooling cost

- In-kind restoration $1175/year.
- Flood resistant restoration $588/year.
- The savings for flood resistant restoration $587/yr.
- The $6055 added cost is offset by energy saving in about 10 years.

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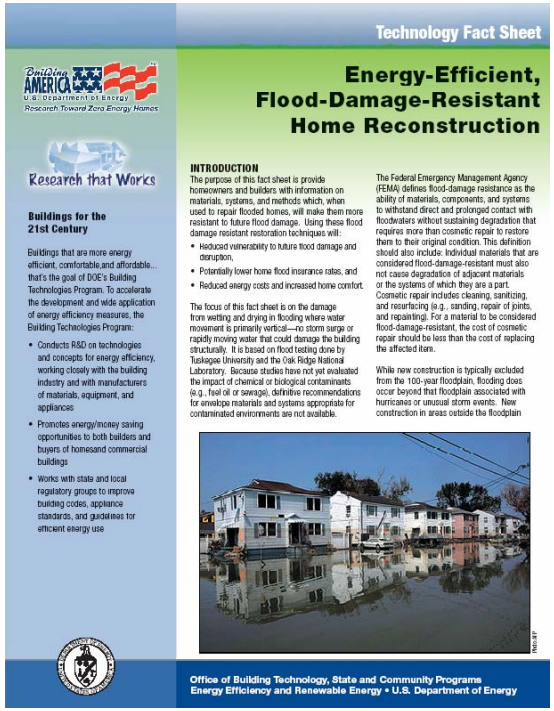
DOE's Fact Sheet—Reconstructing Flood Damaged Homes


Technology Fact Sheet

Energy-Efficient, Flood-Damage-Resistant Home Reconstruction

Research that Works

Buildings for the 21st Century

Buildings that are more energy efficient, comfortable,and affordable... that's the goal of DOE's Building Technologies Program. To accelerate the development and wide application of energy efficiency measures, the Building Technologies Program:

- Conducts R&D on technologies and concepts for energy efficiency, working closely with the building industry and with manufacturers of materials, equipment, and appliances
- Promotes energy/money saving opportunities to both builders and buyers of homesand commercial buildings
- Works with state and local regulatory groups to improve building codes, appliance standards, and guidelines for efficient energy use

INTRODUCTION

The purpose of this fact sheet is provide homeowners and builders with information on materials, systems, and methods which, when used to repair flooded homes, will make them more resistant to future flood damage. Using these flood damage resistant restoration techniques will:

- Reduced vulnerability to future flood damage and disruption,
- Potentially lower home flood insurance rates, and
- Reduced energy costs and increased home comfort.

The focus of this fact sheet is on the damage from wetting and drying in flooding where water movement is primarily vertical—no storm surge or rapidly moving water that could damage the building structurally. It is based on flood testing done by Tuskegee University and the Oak Ridge National Laboratory. Because studies have not yet evaluated the impact of chemical or biological contaminants (e.g., fuel oil or sewage), definitive recommendations for envelope materials and systems appropriate for contaminated environments are not available.

The Federal Emergency Management Agency (FEMA) defines flood-damage resistance as the ability of materials, components, and systems to withstand direct and prolonged contact with floodwaters without sustaining degradation that requires more than cosmetic repair to restore them to their original condition. This definition should also include: Individual materials that are considered flood-damage-resistant must also not cause degradation of adjacent materials or the systems of which they are a part. Cosmetic repair includes cleaning, sanitizing, and resurfacing (e.g., sanding, repair of joints, and repainting). For a material to be considered flood-damage-resistant, the cost of cosmetic repair should be less than the cost of replacing the affected item.

While new construction is typically excluded from the 100-year floodplain, flooding does occur beyond that floodplain associated with hurricanes or unusual storm events. New construction in areas outside the floodplain

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Energy-Efficient, Flood-Damage-Resistant Home Reconstruction

garden sprayer with a commercial mildew remover is recommended. Spraying the surfaces until they were thoroughly wetted is usually effective in eliminating evidence of mold. Floors should be wet-mopped with the same solutions. Although no evidence of mold may reappear during the restoration period, the long-term elimination of mold with these treatments has not been verified.

RECONSTRUCTION PRINCIPLES

There are two considerations in providing flood proofing. They are to: completely exclude floodwater from materials; or, encourage drying of materials that have become wet.

Exclude Water—this approach is at best difficult to accomplish in typical residential construction. Some materials such as plastic foam insulation and ceramic tile flooring absorb little or no water and effectively exclude it from that part of the wall or floor system. However, floodwater can find small cracks in those systems and bypass these impermeable materials and potentially trap water within other parts of the system. Therefore it is wise to provide for at least one means of escape for water in all systems exposed to flooding.

Encourage Drying—this approach acknowledges the probability that water will get into a system and includes appropriate means of escape. At least one means for water or water vapor to escape is identified and maintained and where possible drying in multiple directions is desirable. The rate of drying needs to be consistent with the materials in the systems. For example materials subject rot or bacteriological growth (like wood) must be able to dry faster than materials that are not (like concrete).

Testing has shown that while individual materials may perform satisfactorily, when they are combined into a typical housing assembly or system their performance, or that of materials around them, may degrade and become unsatisfactory. It is therefore imperative that system performance be the criteria for judging the flood damage resistance.

RECONSTRUCTION TECHNIQUES

Site drainage (A)—Flood-damaged homes undergoing restoration may require re-grading of the site around the house to promote drainage away from the structure and promote drying in the crawl space. Provide a 5% (1 inch in 20 inches) slope away from the structure for a distance of 10 feet if possible.

Foundation Vents (B)—Conventional foundation vents may become blocked by debris during flooding, and such blockage could induce unintended hydrostatic loads on the structure and damage it. Operable flood vents are available which are closed prior to flooding and open by themselves during the rising floodwater. Their larger opening during a flood is intended to minimize the potential for blockage from debris. Replace conventional vents with flood vents located as low as practical on the wall to promote draining of the crawl space after a flood. All foundation vents and crawlspace access doors should be fully opened throughout the post flood drying period to permit air to circulate through and dry the crawl space.

Crawl Spaces (C)—Humidity in the crawl space can reach 100% after flooding and remained high for an extended period. In the long term this humidity level can promote mold growth and wood decay. All penetrations in the flooring above a crawl space (e.g., pipes, wires, gaps, etc.) must be effectively sealed to cut off potential pathways that would allow excess moisture and mold to enter the interior of the home. If the crawl space becomes accessible during reconstruction, consideration should be given to regarding the dirt floor to drain the crawl space to the perimeter of the house. After the initial drying of the crawl space floor has been accomplished it is desirable to cover the dirt floor completely with a 6 mil thick polyethylene sheeting vapor barrier. This will help reduce futura moisture levels in the crawl space.

Wood Framing (D)—Testing showed that moisture levels in studs and floor framing will in most cases return to preflood levels during no long-term problems. Many tests of this type showed no visible evidence of mold growth on wood framing. Wood framing is flood-damage-resistant as long as the wall or floor system of which it is a part will permit it to dry to normal levels.

Sheathing (E)—In tests plywood sheathing stood up well to flooding with water remaining as it only lost some evidence of flood exposure. However, when covered with plywood siding, it dried quite slowly which might create long term problems. The use of flood-damage-resistant lap siding (see below) with plywood sheathing is preferred because it is more likely to permit adequate

Water-resistant, fiber-reinforced gypsum Weather Resistant (WR) Sheathing b and mech evidence of this s product not tes

Energy-Efficient, Flood-Damage-Resistant Home Reconstruction

Oriented strand board (OSB) sheathing swelled when subjected to flooding. The impact of this dimensional change on the sheathing's nailing and structural integrity was not evaluated. If these factors were not adversely impacted by flooding, the OSB sheathing would be an acceptable material because it is covered by siding and its post flood appearance is not visible.

Siding (F)—Tests showed that newly installed and painted plywood and hardboard lap siding would withstand damage but remained discolored after washing. Restoration to preflood conditions would require stain sealing and repainting. Older, weathered plywood and hardboard siding and/or siding repeatedly exposed to wetting and drying over several cycles is projected to have much poorer restorability. These materials are not recommended in flood prone areas.

Vinyl and fiber cement sidings both can withstand flood conditions better than hardboard lap siding and plywood siding. Both sidings can usually be restored to preflood conditions through simply washing the portion below flood level. Older vinyl siding and painted fiber cement siding with an oxidized surface may also have to be cleaned above the flood level in order to maintain a consistent appearance. Vinyl and fiber cement siding are recommended for flood exposure.

There was no visible evidence of mold growth from flood exposure on either the inside or the outside surface of the siding materials tested.

Sawn wood corner boards and trim cracked and warped after flood exposure. Replacement of these items with more durable trim materials such as plastic or wood/plastic composites is likely to be more cost-effective than the restoration of these materials.

Wall and Floor Insulation (G)—Fibrous insulation (e.g., fiberglass batt) contributes to higher moisture levels in the exterior wall cavities and below the floor, which can kept the adjacent walls and floor materials wetter longer and could potentially contribute to long-term damage to the subflooring, the floor and wall framing, and the gypsum wallboard. The removal and replacement fiberglass insulation that has been subjected to floodwater is recommended.Spray polyurethane foam (SPUF) insulation tested in the wall cavities enabled the wall board and wood studs in the exterior walls to dry at the same rate as in the interior walls with empty cavities. SPUF absorbs water very slowly and was undamaged by flooding. SPUF did not retain moisture and does not adversely impact the materials around it. There was no visible evidence of mold growth on the SPUF insulation. SPUF is recommended where insulation is subjected to flooding.

Interior Gypsum Wall Board (H)—When conventional paper-faced gypsum board was tested with fiberglass batt insulation on exterior walls, it lost strength and remained wetter longer than gypsum board on interior walls. The gypsum board on interior partition walls dried out and maintained its strength. If gypsum board is able to dry completely, it can be restored to preflood condition with only cosmetic restoration. Although the board supported mold growth on the exposed painted surface, it could be cleaned, sanitized, and restored. No visible evidence of mold growth from flood exposure on the backside or unexposed surface of the gypsum wall board was seen.

Fiber-reinforced gypsum interior wall panels (ASTM C-1278), for example a non-water-resistant product by USG called Fiberock, retained most of its initial flexural strength and dried out during the drying period. Like paper-faced gypsum board, the fiber-reinforced

http://www.ornl.gov/sci/res_buildings/FEMA-Attachments/Flood_damage_reconstruction.pdf

The "bottom line" for homeowners

Using flood damage resistant restoration will:

- Reduced vulnerability to future flood damage and disruption
- Potentially lower home flood insurance rates
- Reduced energy costs and increased home comfort

Your Questions

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